

mechanical means or simply provide tension through gravity. This accumulator/roller is positioned between the intermittent control of the packaging system and the continuous speed underbeam system. This accumulator, along with a variable speed drive mechanism which positively controls the speed of the web while it is subjected to the irradiation energy, effectively 5 accomplishes this product speed translation from intermittent to continuous. The packaging system continues to operate with the intermittent motion that is required for its process while the material is then smoothly conveyed for the irradiation process. This accumulator/roller device may also be used after the material has been irradiation processed to translate this smooth motion back to intermittent if this is required subsequently in the process.

10 The accumulator device can utilize a variety of formats, including a bucket accumulator, a roller accumulator, a linear accumulator, and a slackening trough. An embodiment utilizing a roller accumulator is shown in Figures 1-4, 8A and 8B. Another embodiment using a bucket accumulator is illustrated in Figures 5-6. Another embodiment with a linear accumulator is shown in Figures 7A and 7B.

15 Detailed drawing describing this accumulator device and the drive mechanism for the "underbeam" speed control is seen in the drawings included. This section of the product transport system can be installed in the product line before the "cut" of the product into individual packages. This then allows a means for positively moving a single layer of many products through an electron beam or x-ray irradiation system easily, effectively and provides a 20 means to control the speed, thus the irradiation dose that the product receives.

As illustrated in the figures, the buffer between the index conveyor and the steady rate conveyor of the unit includes an entry region 80 and an exit region 82 at either end of the accumulator. The buffer receives packages at a cyclical rate at the entry region 80. In a preferred embodiment, an irradiation chamber 84 lies within the buffer region. The buffer

moves the packages through the irradiation chamber 84 at a steady rate. The irradiation chamber 84 includes a beam generator or accelerator 78 (described in more detail below), a beam distributor, a target region, a beam generator shield, a target region shield, and a serpentine shield 86. The serpentine shield 86 surrounds the circuitous path through the buffer region. This circuitous path includes an entry point and an exit point. Between the entry and exit point of the path, there is a portion of the path 74 within the irradiation chamber 84 that is substantially straight. This portion 74 of the circuitous path forms the target region of the chamber. Surrounding the substantially straight target region 74, the path may have arcuate portions that lead to and from the target region.

10 The shielding for the irradiation chamber may further include exit and entry shields, such as shutter shield. In this embodiment, the shutter shields open to permit the entry of an untreated package or set of packages into the target region and to permit a treated package or set of packages to exit the chamber through the exit region.

15 The separation station 18 (described in more detail above) may be located in the buffer region preceding the irradiation chamber 84. In such an embodiment, the formed unit 42 is broken into discrete packages 44 prior to passing through the irradiation chamber 84.

Another method for accumulation of the material may simply be accomplished by providing a series of rollers which allow the material to "hang" in the radiation shielding labyrinth entrance in sufficient length to bend around the shielding material.

20 The conveyance of the product in this for also allows for easier movement of the product or material into and out of the irradiation shield or chamber. Since one of the primary design issues with these type system is to allow for product entrance and exit from the shield while at the same time effectively trapping or reducing the x-ray energy leaking from the shield. The conveyance of products in this type of low profile format minimizes the x-ray leakage and

therefore allows for the shielding to be designed in a more compact and economical manner.

In this process it is important to be able to correlate the dose delivered to a particular product for the purpose of process certification. This provides the user with the means of tracability for processing food stuffs, medical product sterilization and overall process control.

5 The integration of these two processing systems (irradiation and packing) which includes the parameters from the irradiation system and the tracking of individual products in the packaging system permits strict control requirements such as those in product sterility processing. This provides a means for process control and validation of the product coming off the packaging system for individual products that is not done today in irradiation processing. By providing 10 specific signals for beam intensity, beam scanning distribution, energy stability etc, to the packaging system PLC this tracability of sterility can easily be accomplished.

Irradiation processing of materials, specifically electron beam irradiation processing of materials, which are done in the format detailed above are typically described as having been "single sided processed". This term, as it is used in the industry, refers to the fact the electron 15 beam is delivered to the product from one direction only and the product has not been "flipped over" or treated from the opposite side with electrons, i.e., "single sided processing". The limitation in this style of one sided treatment is that the energy of the electron must then be sufficiently high to penetrate the product being treated to effectively treat the "whole" product from this single side delivery of electrons. This requirement for the higher energy accelerator 20 means that more radiation shielding must be used to limit the x-ray leakage which increases the overall system cost. One embodiment of this invention is to utilize a high energy, low power accelerator to treat the irradiated product in the manner described above with sufficient energy to treat the whole product.

When material and product densities are sufficiently low the energy of the accelerator

may be reduced to a minimum level to allow for reduced size, radiation shielding and power requirements.

One might imagine that if there was a means for delivering the electrons from a single side in a manner to more effectively distribute the electron energy in the product and not require 5 the typical increase in the system energy that a more cost effective and smaller system could be produced. One means for accomplishing this is to provide reflector plates in the beam chamber around the exit of the scanner which are positioned to deflect a portion of the electron beam and low energy scatter electrons into the material. These deflected or reflected electrons enter the material from wide angles and provide dose increases around the edges of the product being 10 treated. This effect can improve the dose distribution and irradiation process uniformity.

Radiation dosimetry is the typical method for qualifying whether a particular product has been properly treated. One unique concept for this type of system, where the label for each package is individually printed after the package has been sealed and before it has been irradiated, is to use radiation sensitive inks for a portion of the label. This radiation sensitive ink 15 will change color during the irradiation process and be a clear indicator that the package has been treated. This may or may not be utilized in the quality control process for assurance of product treatment.

An example of one type of accelerator that may be used in this application is the DC, 20 Dynamitron system described here, works on a similar principle as a television tube. Free electrons are generated by heating a filament which is part of the electron gun assembly. A high voltage of the correct polarity draws the electrons away from the gun and accelerates them through the vacuum tube. The electrons gain energy and velocity as they are accelerated in the vacuum tube. As the beam of electrons passes from this acceleration or beam tube, they travel down a vacuum beam line and may pass through the scan magnet or other types of beam

distribution devices which are known in the art. This magnet, and its oscillating magnetic field, sweeps the beam back and forth across the scan window. At the scan window the electrons pass from the vacuum chamber into the air where they are delivered directly to the product or to an x-ray convertor to provide photons for x-ray processing

5 Electron beam system for this type of process range from low voltages in the 100's of kV range up to accelerators that deliver electrons to 10 or more mega volts. Electrons accelerated to an energy of 5 MeV are traveling at approximately 99.6% of the speed of light, or nearly 300,000 km/sec, when they enter the product. The amount of beam current, which partially determines the processing rate is measure in micro or milliamperes. It is interesting to
10 note that 1 mA of beam current represents about 6 million billion electron particles every second.

Where the objective of the electrons generated in a television is to create a picture, a Dynamitron bundles electrons into a 3 to 5 cm diameter beam to irradiate materials. The enormous number of electrons and the high acceleration voltage produces rapid reactions by
15 operating directly on the molecules within the product. This produces an efficiency that is outstanding when compared with other methods such as heat, light, and chemical reagents.

There are many different type of accelerators available to provide this type of processing capability, to one skilled in the art of electron beam system this would be understood. The Dynamitron described here is but one example, but other types of AC accelerators such as
20 multiple and single cavity Linac's, single cavity multi-pass Rhodotrons or DC ICT's (Insulated Core Transformers) or single gap DC accelerators may be used.

In view of the foregoing, it will be seen that the several advantages of the invention are achieved and attained.

The embodiments were chosen and described in order to best explain the principles of

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the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated.

As various modifications could be made in the constructions and methods herein described and illustrated without departing from the scope of the invention, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative rather than limiting. For example, while the present invention discusses the details of an electron beam device for the sterilization process, other forms of electromagnetic sterilization may be used. Also, while an active beam scanner is described, it will also be appreciated that other devices to distribute the beam in the target region can be used, such as a diffuser. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims appended hereto and their equivalents.